CLIMATE RISK PROFILE SERIES

ADAPTING GREEN INNOVATION CENTRES TO CLIMATE CHANGE: ANALYSIS OF VALUE CHAIN ADAPTATION POTENTIAL

Groundnut, Soya Bean, and Milk Value Chains in Eastern and Southern Provinces, **Zambia**

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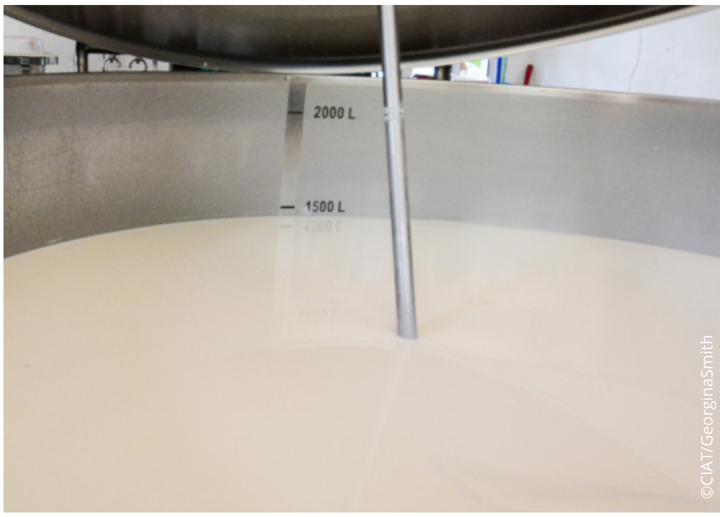

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CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

ABOUT THIS REPORT

Climate change is affecting agriculture more than any other sector. Increased frequency and severity of drought, flood, heat, and unseasonable rainfall heavily impact rainfed agriculture, ultimately resulting in production losses. In that context, The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) through its climate action lever, are developing climate risk profiles for agricultural value chains in developing countries at the national and subnational level. These profiles build on past work conducted by CIAT and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)in collaboration with the World Bank and other partners, including FAO, USAID, DFID[1].

The present report aims to provide a climate and vulnerability analysis of the Green Innovation Centres (GIC) target commodity value chains. Herein we identify climate change- related vulnerabilities, hazards, and opportunities for adaptation to the same. Ultimately, our goal is to foster awareness of risks and adaptation priorities in the selected value chains and inform climate investments and planning through the recommendations on priority innovations to manage climate risks.

The report begins with an extensive literature reviews of the selected value chains and their key challenges and adaptation strategies. Climate hazards and crop suitability modelling offer insights into potential future scenarios under climate change. These results inform potential adaptation approaches, which are prioritized by in-country experts and stakeholders through an online survey. The top-rated adaptation priorities undergo a cost-benefit analysis. Finally, the results are peer-reviewed by the GIC country office and the Alliance scientific staff.

The **Green Innovation Centres** for the Agriculture and Food Sector (GIC) founded by German Federal Ministry for Economic Cooperation and Development (BMZ) and led by the German Agency for International Cooperation (GIZ) in collaboration with local ministries and programmes, aims to promote agricultural innovation under the *ONEWORLD No Hunger* initiative. Through the GIC, GIZ aims to generate employment raise farmers' income, and improve farmers' education and skills by funding training in good agricultural practices, water management, post-harvest processing, and entrepreneurship.

Planning, data collection and stakeholder engagement → **Climate risk assessment** → **Identification of adaptation strategies** → **Production of the country climate profile and validation**

- Planning, data collection and stakeholder engagement:
  - Literature review (key documents and datasets)
- Climate risk assessment:
  - Hazard analysis
  - Crop suitability modelling
- Identification of adaptation strategies:
  - Detailed review
  - Gap analysis and identification of climate adaptation
  - Online survey
  - CBA analysis
- Production of the country climate profile and validation:
  - Peer-review

1 https://ccafs.cgiar.org/publications/csa-country-profiles

HIGHLIGHTS

- Although Zambia's agricultural sector is a vital contributor of employment and livelihoods and supports food security, still, problems like malnourishment, stunting, and wasting occur at high rates among Zambia's children. **(Chapter 2, pg.12-13)**
- This climate risk profile focuses on groundnuts, soya beans, and milk, because these value chains entail different forms of nutritional, economic, and cultural value. **(Chapter 2, pg.15-19)**
- In addition, the Zambian agricultural sector faces a variety of challenges, including climate change-related risks, expensive inputs, low uptake of good agricultural practices, and a need among farmers for additional training in adaptive skills and technologies. **(Chapter 2, pg.19-20)**
- To support adaptation to climate change, numerous government policies, plans, and programs have been established, including Zambia's National Adaptation Programme of Action (NAPA), 2010 National Climate Change Response Strategy, 2016 National Policy on Climate Change (NPCC), and 7th National Development Plan. **(Chapter 3, pg.21-22)**
- In addition, numerous international partners support the agricultural sector in a variety of ways, for example, by training farmers in useful skills and technologies. **(Chapter 3, pg.22)**
- Climate modeling predicts that dry spells, extreme heat events, flood risk, and moisture stress will increase in Eastern and Southern Provinces, along with localized risk of erosion. **(Chapter 5, pg.27-28)**
- Currently, both groundnuts and soya beans are highly suitable crops in Eastern and Southern Provinces; however, slight, localized decreases in suitability are predicted, especially in Southern. **(Chapter 5, pg.31)**
- The most pressing climate-related hazards are droughts and floods in the groundnut value chain; diminished rainfall and changing temperatures in the soya bean value chain; and droughts and extreme rainfall in the milk value chain. **(Chapter 5, pg.34-35)**
- The Green Innovation Centre (GIC) in Zambia has been using different participatory approaches to strengthen farmers' adaptation to climate change. **(Chapter 6, pg.37)**
- Although the use of minimum tillage and good management practices in the groundnut value chain and the use of an improved variety of soya beans are both profitable and have a relatively short payback period, these innovations carry considerable risk. **(Chapter 6, pg.45)**
- Conclusively the adaptation potential for the selected value chains is promising. Financial support, however, can ensure that most smallholder Zambian farmers will have good outcomes from implementing these adaptation strategies. **(Chapter 7, pg.49)**

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AEDD	Environment and Sustainable Development Agency
CDD	Consecutive Dry Days
CEDEAO	Economic Community of West African States
CIV	Centre d'Innovation Verte
CNCC	National Climate Change Committee
DNA	Direction Nationale de l'Agriculture (National Directorate of Agriculture)
DNGR	Direction Nationale du Génie Rural
DNM	National Directorate for Meteorology
GAPs	Good Agriculture Practices
GDP	Gross domestic product
GIZ	The German Agency for International Cooperation
IER	Institute of Rural Economy
IICM	Integrated Initiatives for Mali's Economic Growth
IFM	Mango Interprofession
IRR	Internal rate of return
LOA	Agricultural Orientation Law
MEADD	Ministry of the Environment, Sanitation, and Sustainable Development
MSP	Multi-Stakeholder Platform
NGO	Non-governmental organizations
NPV	Net present value
ORM	Office Riz Mopti
PANC	National Climate Action Plan
PASSIP	Support Program for the Local Irrigation Sub-Sector
PCDA	Competitiveness and Agricultural Diversification Program
PDA	Agricultural Development Policy
PNCC	National Climate Change Policy
PNISA	National Agricultural Investment Program
RCP	Representation Concentration Pathway
SNCC	National Climate Change Strategy
SOCAFON	Societe cooperative artisanale des forgerons de l'office du Niger
SRI	System Rice Intensification
SRP	Sustainable Rice Platform
PPU	Deep placement of super-granulated urea
USAID	United States Agency for International Development

1. INTRODUCTION

Zambia is a sub-tropical country located in southern Africa. It has the third largest water resource in Africa, Zambezi River, yet food production is predominantly rain-fed. This fact makes agriculture a climate change-sensitive and risky venture for many small-scale farmers who produce the bulk of Zambia's food. As is clear in its national agriculture policy and in Zambia's overarching Vision 2030 long-term plan, the government of Zambia recognizes the central role that agriculture plays in its economy and has established various mechanisms to address challenges in the sector. Priority areas include increasing productivity and farm incomes, strengthening farmers' adaptive capacities, improving food and nutritional security, mechanizing agriculture, creating job opportunities, and building resilient farming systems.

In support of this vision, the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned Green Innovation Centres (GIC) for the agriculture and food sector as part of the "ONE WORLD – No Hunger" initiative in 15 countries, among them Zambia. Its main objectives include boosting 70,000 smallholder farmers' incomes by 25%, generating employment, and raising literacy levels through further education for women and youths. Supported by the Ministry of Agriculture (MoA), and implemented by Community Markets for Conservation (COMACO), this initiative focuses on the groundnut, soya bean, and milk value chains in two provinces, namely Eastern and Southern Zambia (Figure 1). This short but informative document therefore aims to teach stakeholders about these value chains, and educate policymakers and the private sector about the threats and opportunities of climate change in Zambia's groundnut, milk, and soybean value chains. It also seeks to promote the incorporation of context-specific adaptation strategies and to present investment opportunities for climate-smart agriculture (CSA).

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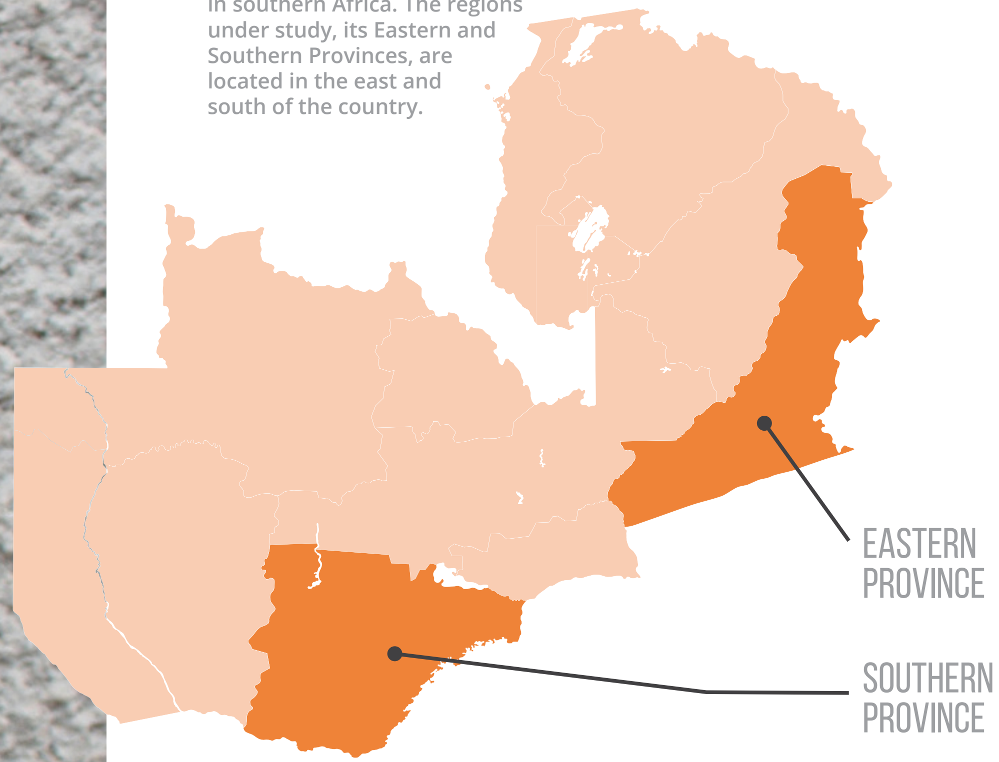
Figure 1. Map of the selected regions in Zambia



This profile has six sections, each reflecting an essential analytical step in understanding current and potential adaptation options in the selected value-chain commodities. The first describes the importance of agriculture to people's livelihoods in the four departments. Section two highlights the policies, strategies, and programs implemented in the three value chains that address climate change, while the third section discusses the governance and institutional resources and capacity. The fourth section discusses the main climatic hazards affecting the three value chains and presents climate modeling results for projected climatic change-related hazards and crop suitability maps. Additionally, it offers an analysis of vulnerabilities and risks posed by these hazards to the respective value chains. The ongoing on-farm adaptation strategies adopted by farmers to cope with these hazards as well as the cost benefit analysis results are discussed in the fifth section. The sixth section provides a synthesis and recommendations.

2. AGRICULTURAL CONTEXT

KEY MESSAGES

- The agricultural sector is vital to employment, livelihoods, and food security in Zambia.
- Nonetheless, Zambia still faces high levels of undernourishment, stunting, and wasting among its children.
- Groundnuts are a crucial food crop, widely grown, nutritious, and economically important; they are often cultivated on small farms with significant involvement by women.
- Soya beans, meanwhile, are rich in protein and oil, and at many stages of production, women comprise the majority of workers.
- Milk production, meanwhile, has both economic and cultural importance; many farmers own livestock for a variety of reasons, but not all of them produce milk.
- The Zambian agricultural sector faces several challenges, including climate change and variability, expensive inputs, low uptake of good agricultural practices, a lack of transparency among businesses, and poor governance.

Zambia has ten administrative regions, namely the Northern, North-Western, Eastern, Western, Southern, Central, Copperbelt, Lusaka, Luapula, and Muchinga Provinces. Eastern Province, which has eleven districts, is an estimated 51,476 km^2 in size, and borders Malawi to the east and Mozambique to the south. Its capital is Chipata. Southern Province is significantly larger and has thirteen districts, occupying an estimated land area of 85,283 km^2, and its capital is Choma. The Zambezi River borders Southern Province.

2.1. Economic relevance of farming

Zambia's economy is hugely dependent on mining. **However, agriculture is a key sector that employs 67% of the working population, supports 85% of Zambian livelihoods, and contributes to national food security.** In 2019, the agricultural, forestry, and fisheries sector contributed 3% to the total national gross domestic product (GDP). (World Bank, 2020; ZamStats, 2019). Zambia exported agricultural products worth US$ 0.8 billion in 2014 (USDA, 2015), but the value of exports decreased to around US$ 403 million in 2019 due to price volatilities and trade restrictions among other factors (Mulenga, Kabisa, & Chapoto, 2019). Major export crops include sugar, which represents 26% of the total value of agricultural exports, followed by tobacco (17%), corn (8%) and cotton (8%). Production and sales in the horticultural sector have experienced steady growth. Exporting roses, for example, accounted for US$ 26 million in 2013 alone (USDA, 2015). The estimated annual consumption of horticultural products is 1 million tonnes, worth more than US$ 330 million, and this value is expected to rise to US$ 500 million by 2020 (Mulenga, Kabisa, & Chapoto, 2019).

2.2. People and livelihoods

In 2010, the population of Zambia according to the census was 13,046,508, of whom 6,394,455 were males (49% of the population), while 6,652,053 were females (51%). 61% of the population lived in rural areas. The population of Zambia was projected to rise at an average rate of 3% per year over the period 2011-2020, and is expected to hit 18 million in 2020 and 30 million in 2035 (Central Statistical Office, 2013). The population of Zambia is young; 48% is 0-14 years of age, 49% is 15-64 years of age, and only 3% is 65 or more years old (ZDHS, 2020). Eastern Province had a population of 1,592,661, and Southern Province of 1,589,926; each province accounts for roughly 12% of the total Zambian population (Infographic 1). In both provinces, the female population was higher than the male population; Eastern Province contained 784,680 males and 807,981 females, and Southern Province had 779,659 males and 810,267 females. A large percentage (>75%) of the population was rural. The total labor force constituted more than half of the provinces' population, but the rates were exceptionally high in Eastern Province at 70% (Figure 2).

Access to basic necessities and resources like drinking water is relatively high. A majority of the households in Eastern (79%) and Southern (66%) Provinces have access to an improved water source (Infographic 1). The most common water sources include piped water, standpipes, tube wells, boreholes, protected dug wells, and springs. Access to piped water is predominant in urban dwellings, compared to rural areas where households obtain their water mainly from tube wells and boreholes (ZDHS, 2020).

In terms of food security and nutrition, due to low household incomes and educational levels, undernourishment, stunting, and wasting levels are still high among children (ZDHS, 2020). In both provinces, about 45% of children under the age of five are stunted, which means that they are short for their age; and 5% are wasted, that is, thin for their height. Nationally, 12% of children are underweight, meaning that they are thin for their age; and 5% are overweight, which means they are heavy for their height (ZDHS, 2020).

Overall, 34% of households have electricity; however, only 18% in urban areas and a mere 2% in rural areas use it for cooking. Firewood, used by 79% of households, is the most important cooking fuel in rural areas; while charcoal, used by 75% of households, is more common in urban areas (ZDHS, 2020).

Regarding educational attainment, among the 15-49 year-old age group, literacy levels are higher for men at 82% than for women at 66%. With fewer than 10% pursuing education beyond secondary school, higher education is rare (Infographic 1).

Regarding information and communications technology services, 74% households own a mobile phone, 47% possess a radio, and 37% have a television. Internet usage is 7%. The most common means of transport is bicycles, which are used by 38% of households, while just 7% of households use cars and trucks. 53% of households own agricultural land (ZDHS, 2020).

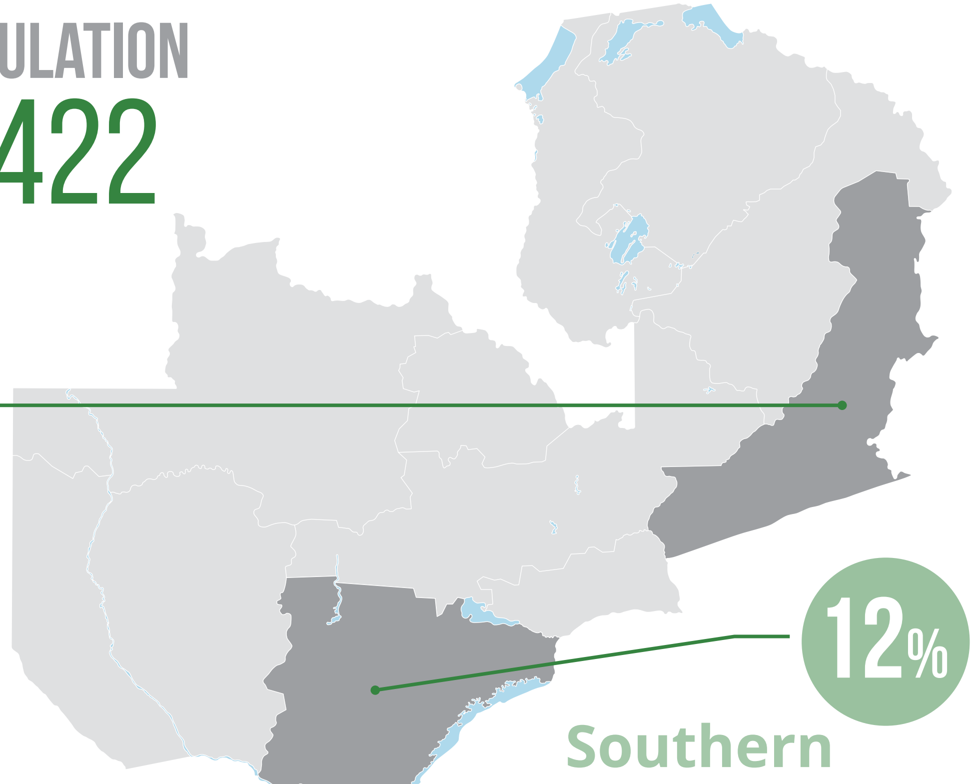
2.3. Agricultural activities

Zambia has three agro ecological zones (AEZs) identified by their rainfall, temperature and soil characteristics. These AEZs condition agricultural activities such as the cultivation of crops and keeping of livestock. Region I, which is 17.3 million hectares (ha) in size, encompasses the arid zone of Southern and Eastern Provinces and the semi-arid zone of Western and Southern Provinces (Ndiyoi & Phiri, 2010). This region receives 800 mm annual rainfall and typically has short cropping seasons (80-120 days), so it is favorable for cultivating millet and sorghum and for keeping livestock. Western, Eastern, Central Provinces, and some portions of Northern Province, are covered by Region II, which is 27.4 million ha in size (Ndiyoi & Phiri, 2010). This region is split further into two sub-regions. **Located in the fertile plateau, Region II-a features many crops grown under irrigation.**

Figure 2. Agriculture and livelihoods

DEMOGRAPHICS

ZAMBIA'S POPULATION
17,885,422



12%
Eastern
2,065,590
inhabitants

50.36% | 49.64%

87.3%
of which are rural

12%
Southern
2,135,794
inhabitants

50.39% | 49.61%

73.1%
of which are rural

ACCESS TO BASIC NEEDS

% of the population suffering from **absolute poverty**

Eastern	70%
Southern	58%

Youth literacy rate (15-30 years)

Eastern	75.2%
Southern	91.3%

ND: Not Disclosed

% of households with access to **electricity for lighting**

Eastern	Southern
8%	25%

% of total households with access to **electricity for cooking**

Eastern	Southern
2.3%	15.6%

% of households with access to **potable water**

Eastern	Southern
76.0%	75.1%

FOOD SECURITY

	Eastern	Southern
Population suffering from **food poverty**	55.9%	38.1%
% of **household income** spent on food	53.2%	44.3%
% children **stunting**	45.6%	43.7%
% children **wasted**	4.2%	6.7%

FARMING

	Eastern	Southern
Arable land	3,060,000 KM²	3,349,817 KM²
as a % of total land area in the province	59%	50%
% of people **employed** in **agriculture**	62.4%	40.9%

LAND USE

Total number of ha under:

KEY: EASTERN SOUTHERN

Crop	Eastern	Southern
Maize	283,524	336,824
Rice	1,178	N/A
Sunflower	57,335	29,558
Soya beans	55,229	10,992
Irish potato	73	239
Burley tobacco	7,073	567
Bambara nuts	107	1,095
Sweet potatoes	1,785	15,450
Wheat	N/A	2,102
Sorghum	129	16,600
Millet	127	3,507
Ground nuts	98,708	37,574
Seed cotton	58,109	22,552
Virginia tobacco	1,526	2,271
Mixed beans	3,194	2,863
Cowpeas	292	8,771
Cassava	15	17

Total number of **livestock breeds**

Eastern	Southern
601,921	1,315,238
359,247	1,290,856
30,524	62,586
306,527	181,783

Sandy soil is predominant in Region II-b; both livestock production and the farming of crops such as cashew nuts, rice, and cassava are common. The growing season ranges from 100-140 days in Region II-b. Region III occupies 46% of the national area and covers the Northern, Luapula, and Copperbelt Provinces (Ndiyoi & Phiri, 2010). This region receives more than 1000 mm annual rainfall, enjoys long growing seasons of up to 150 days, and is characterized by moderately fertile soils, with strongly acidic soils in some areas. The presence of acidic soils limits the growth of some cereals and legumes. However, the long growing seasons make the region ideal for growing perennials such as sugarcane, coffee, and rice.

In 2014-2015, there were 1,473,547 agricultural households. Men, compared to just 22% women; head a majority (78%) of these households and majority of both heads were in the 35-39 age group Central Statistical Office, 2016) In 2019, about 1,424,387 households were involved in crop production, while 671,445 raised poultry, 949,541 kept poultry, and 16,953 farmed fish. The horticulture sector also involved over 300,000 smallholder-farming households. Farmers are broadly grouped into three categories. Large-scale farmers who cultivate more than 20 ha are dependent on mechanization, utilize new and improved technologies, and produce for markets. Medium-scale farmers cultivate between 5 and 20 ha and keep some of their household produce. Small-scale farmers cultivate less than 5 ha, grow food for subsistence purposes, and depend on low-cost farming technologies (Ndiyoi & Phiri, 2010).

The rate of fertilizer usage among smallholder farmers is currently 58%. Across the provinces, Copperbelt recorded the highest rate of fertilizer usage at 77%, and Western Province recorded the lowest rate at 12%. The average use of fertilizer per ha in Zambia was 117 kilograms (kg/ha) (Mulenga, Kabisa, & Chapoto, 2019).

2.4. Agricultural value chain commodities

2.4.1. Groundnuts

Groundnuts, also known as peanuts (*Arachis hypogaea*), are legume crops widely grown in Zambia for their nutritional and economical value. Consumed raw or processed, groundnuts are a major source of protein in Zambian diets (Desmae & Sones, 2017). In Zambia, groundnut farming is small-scale, with a high degree of participation by women across the entire value chain. Hence, groundnuts are referred to as female crops because of the important role women play in planting and harvesting, as well as in post-harvest management and processing. Men are primarily involved in input supply and marketing of inputs.

In Zambia, several groundnut varieties are grown. These differ based on their growth habits, days to maturity, seed sizes, resistance or tolerance to disease, potential yields, and oil content (Mukuka & Shipekesa, 2013). They include the Msekera variety (MGV-4) whose kernels are red, uniform, and medium in size, and contain up to 50% oil; and the Chishango variety, whose kernels are tan to pink in color, uniform, medium-sized, and contain 47% oil content. Other varieties include Makulu Red, Champion, Chalimbana, MGV-2, MGV-5, Chipego, Comet, and Katete.

Groundnuts are the second most important food crop after maize in terms of production and account for 9% of the overall cultivated land in Zambia (Mukuka & Shipekesa, 2013). In 2019, groundnuts were cultivated by 46% of all agricultural households. With 130,825 metric tonnes produced during the same season, the total area under groundnut production was 276,383 ha (Mulenga, Kabisa, & Chapoto, 2019). Eastern Province is the largest groundnut producer and accounts for a third of the total groundnut production area, followed by Northern (19%) and Southern (14%).

Acquisition of seeds, labour, and farm inputs for pest and disease management are important activities before groundnut planting. Extension services and advice are especially crucial for easier access to information about the planting calendar and choice of seed varieties. Seed companies are active distributors of certified and quality groundnut seeds. Major seed companies include Zamseed, Pannar, and Seed Co. However, there are also small- and medium- scale agro-dealers like Shifa and Mania who are located in Chipata, Keson in Katete that support seed distribution (Mukuka & Shipekesa, 2013).

Groundnuts require deep, fertile, well-drained soils for good yields; therefore, site selection and land preparation are important. In most households, planting is done using hand hoes, making it a labour-intensive activity. Planting is undertaken by both men and women on their own plots or jointly if the plots are managed together. This activity can take up two to three days, especially for adult women in a plot of 0.25 ha (Mukuka & Shipekesa, 2013).

Field management practices like weeding and fertilizer application, pest and disease management, and harvesting are key on-farm activities for increased groundnut productivity. In the first 45 days after planting groundnuts, the plots must be weeded, which is a labour-intensive process. Some farmers prefer to use animal draught power to save time. However only 5% of farmers use this practice (Mukuka & Shipekesa, 2013). Harvesting is dependent on the maturity of the pods and kernels, which varies across varieties. Harvesting is manual or mechanical. Many farmers manually harvest groundnuts, a process that involves pulling the plants from the ground by hand or loosening the soil first with a hand hoe, then drying them overnight, curing the pods, and then picking the pods off the plant.

At the post-harvest stage, the sorting of immature and discolored pods precedes threshing, shelling, and storing the groundnuts. Hand shelling is most common, even though mechanical and motorized shellers make this operation easier. A task mostly done by women and children. Groundnuts are preserved in their shells because they reduce their susceptibility to insect, pest, or mold infections. Most of the groundnuts produced are consumed at home.

The surplus is sold at local markets, where it is assembled and traded in different centres in Zambia or neighboring countries. Traders buy from farmers at low prices and can resell at Lusaka's Soweto market at an average price that is triple farm-gate prices, or at the Kasumbalesa border at higher prices than Lusaka's Soweto market. In some situations, there is barter trade of groundnuts for other merchandise like clothing or household items.

2.4.2. Soya beans

Soya beans or soybeans (Glycine max) are a legume commonly grown for their nutrient-dense qualities; they contain 42% crude protein and 20% oil. Soya products include soya chunks and meals, while cakes used as animal feed are by-products. In Zambia, both small- and large-scale farmers grow soya beans as an industrial crop in rotation with maize; they do well in AEZ regions I and II (Lubungu, Burke, & Sitko, 2013). Safari, Samba, Semeki, Soricco, and Spike are among the major soya bean varieties in Zambia. Generally, more women farmers are involved in soya bean farming than men. Men, however, dominate land planning (66.7%), market transport (65.0%) and weeding (56.7%), while women dominate planting (74.2%), shelling (66.7%), bagging (71.7%), and marketing (82.0%) (Mafimisebi et al, 2015). In the 2018/2019 season, the area covered by soya beans significantly increased to 236,601 ha from 75,621 ha in the 2014-2015 agricultural season. Production of soya beans was estimated at 281,389 metric tonnes with average soybean yields of 1.10 mt/ha. Men and women are both engaged in the production of soya beans.

At the input level, sourcing the appropriate

seeds is key. Although improved soya bean varieties exist, farmers often use local, recycled soya bean varieties. They do this because these soya beans are self-pollinating and inexpensive, and can be recycled for a long time without losing vigor (Lubungu, Burke, & Sitko, 2013). Other essential inputs include productivity-enhancing rhizobium inoculant, pesticides and herbicides for pest control and disease management (ZARI, 2013). Important input suppliers include large-scale seed companies, small and medium-sized agro-dealers, businesses, and often farmers who grow their own seed from their harvests.

Land preparation, planting, harvesting, and crop management practices such as first and second weeding are important activities during on-farm production. Soya beans require well-drained soils and reliable rainfall. Insecticides like Karate brands are used to control insects that eat leaves, while powdery mildew is managed by fungicides (Seed Co, 2019). When the pods are dry and brown in color, harvesting starts. Popular harvesting methods include pulling and cutting by hand. In larger plots, the use of a mower and combined harvesting are preferred. After threshing, harvested plants are dried to reduce the aflatoxin risk.

Once threshed, soya bean seeds are sorted, cleaned, and packed in clean bags for storage in a cool place. Less commonly, farmers sell the soya beans directly to suppliers, assemblers, and processors for further value addition. Important service providers at the post-harvest and processing stage include large wholesalers and processors like COMACO and Lusaka-based animal feed and oil processors. Small- and medium-scale assemblers and traders are also important players and act as links between farmers and processors (Lubungu, Burke, & Sitko, 2013).

2.4.3. Milk

In Zambia, dairy farming is an important economic and cultural industry. Many households keep cattle for economic status, for draught use, and for subsistence purposes. Approximately 300,000 households own dairy cattle; however, only 4000 smallholder farmers produce milk for formal markets (Mumba, Pandey, & Jagt, 2013).

For successful dairy farming in Zambia, essential inputs include sourcing of water, acquisition of good-quality breeds, feed, and veterinary and other extension services. Milk production requires that each dairy cow has access to at least 30 litres of water per day and to enough feed. The value of feed is determined mainly by its energy and protein content. Common animal feeds used for dairy farming include grasses like rhodes grass, maize, legumes like desmodium, concentrates like maize bran, hay, and silage (Pandey & Voskuil, 2011). Extension services are usually offered by the government, with additional support from the private sector in providing information and knowledge for proper dairy management.

During on-farm production, feeding, pest and disease control, and milking are important activities. Farmers require feed rations that are well balanced in energy, protein, and minerals. Otherwise, they risk nutritional diseases like urea poisoning[2], acidosis[3] or ketosis[4] (Pandey & Voskuil, 2011). Proper animal husbandry practices during this stage are also vital to ensure healthy animals and high milk production. Milking, meanwhile, needs to be handled hygienically to reduce milk contamination. Hygenic practices include washing the hands before milking, washing each cow's udder, and using clean collection containers.

Milk is either sold raw through informal channels, such as by milk hawking, or through formal market channels at established milk collection centres. Important milk processors in Zambia include Varun milk, Finta, Parmalat (recently sold to Lactalis) and ZAMMILK. They buy milk from farmers and pay them on a monthly basis. At the product marketing stage, important activities include linking farmers to markets through cooperatives, and pricing, promoting, and selling milk and its products. Major market actors include supermarkets, groceries, hotels, and small-scale vendors who sell the raw milk and other milk products to consumers (Mumba, Pandey, & Jagt, 2013).

2 Urea is used in feed supplements as a source of non-protein nitrogen (NPN). When, however more urea is ingested than can be metabolized by rumen species, ammonia is absorbed from the rumen into the blood. Too much blood ammonia can lead to poisoning.

3 When the animals eat too little fibrous feed (fodder) and too much feed rich in soluble carbohydrates like grain, maize and maize-bran, or brewers' grain, the acidity in the rumen becomes too high and the pH drops below normal (5.6).

4 Ketosis is a metabolic disease of lactating cows that occurs within a few days after calving. It might occur if an animal has received a ration that was too rich in energy when she was dry.

2.5. Agricultural sector challenges

Climate change and variability in Zambia have become a major developmental challenge for the agriculture sector. In the 2018-2019 agricultural season for example, there were serious rainfall deficits, especially in the western and southern parts of Zambia, that led to food insecurity, and in particular reduced cereal production (Mulenga, Kabisa, & Chapoto, 2019).

Small-scale farmers who constitute the majority of the food producers are constrained by the high cost of improved seeds and other inputs. Moreover, high poverty rates and poor access to financial services have compounded the challenges the sector faces. Many farmers lack the purchasing power to afford better technologies, which further reduces their ability to respond to or recover from recurrent climate-related hazards such as droughts and floods.

Besides adverse climate-change impacts, poor yields are associated with low uptake of good agricultural practices like the use of inoculum for soya beans, early planting, integrated pest and disease management for groundnut, and proper animal husbandry for dairy farming. Many farmers still do not have access to education and training programmes to increase their knowledge and upgrade their skills. Sub-optimal infrastructure, such as poor rural road networks, inadequate storage or warehouses, and a lack of information services, further constrains the development of these value chains, hinders the uptake of new adaptive strategies, and limits access to markets (Lubungu, Burke, & Sitko, 2013; Siamabele, 2019).

Poor governance and limited business-related transparency in the selected value chains together mean missed opportunities for higher incomes and other improvements. For instance, in the milk value chain, prices are dictated by processors; therefore, the possibility for farmers to influence pricing based on their production costs is quite limited (Kawambwa et al, 2014).

3. POLICIES, STRATEGIES AND PROGRAMS ON CLIMATE CHANGE

KEY MESSAGES

- » Mali has developed a strong framework of environmental law and policy, including the National Climate Change Policy (PNCC), the National Climate Change Strategy (SNCC), the National Climate Action Plan (PANC), the Agricultural Orientation Law (LOA), the Agricultural Development Policy (PDA), and the National Agricultural Investment Program (PNISA).
- » In keeping with these policies, numerous programs have been developed, including some that are relevant for the rice, potato, and mango value chains, such as the Support Program for the Local Irrigation Sub-Sector (PASSIP), the Competitiveness and Agricultural Diversification Program (PCDA), and the Integrated Initiatives for Mali's Economic Growth (IICM) project.
- » These programs could strengthen their responsiveness to local context and cross-sectoral linkages, as well as supporting additional ministries to engage in implementation.

Zambia acknowledges, as a party to the United Nations Framework Convention on Climate Change (UNFCCC), the importance of addressing the adverse effects of climate change. Zambia plans to develop policies and mechanisms under this convention to guide adaptation to and mitigation of climate change. The development of a National Adaptation Programme of Action (NAPA) to define priority measures needed to respond to climate change was one such framework. The proposed adaptation initiatives for the agricultural sector under the NAPA included strengthening Early Warning Systems (EWS) to support timely dissemination of meteorological knowledge, promoting irrigation and the efficient use of water resources, and diversifying crops and livestock with a view to improving nutrition and food security.

The 2010 National Climate Change Response Strategy was developed to enhance adaptation and disaster risk reduction, mitigation, and low carbon development mitigation actions. The 2016 National Policy on Climate Change (NPCC), meanwhile, aims to foster a prosperous and climate-resilient economy by 2030. This policy guides relevant ministries and institutions to implement climate change programmes and sets out clear entry points to achieve a climate resilient economy. Several measures include the promotion and implementation of sustainable land-use management practices; mainstreaming of climate change into policies, plans, and strategies; and communication and dissemination of climate change information to increase awareness and understanding of its impacts. Other policies and sectoral strategies that contribute to resource conservation and climate change adaptation and mitigation include Nationally Appropriate Mitigation Actions; the National Strategy for Reducing Emissions, Deforestation, and Forest Degradation (REDD+); the 2007 National Policy on Environment; the 2014 National Agriculture Policy; and the 2008 National Energy Policy.

Policies supporting the expansion of the selected value chains include the 7th National Development Plan to create a diversified and export-oriented agricultural sector by accounting for climate change effects. The plan seeks to encourage diversification within the agriculture sector, boost investment in agricultural infrastructure, broaden access to finance for production and exports, and improve production and productivity. The goals of the Dairy Industry Development Act (2010) include establishing a Dairy Industry Development Board, augmenting milk production in order to fully utilize the capacity of processing facilities, ensuring collaboration and participation of all stakeholders within the dairy industry, and promoting self-regulation of the dairy industry through the development and use of codes of practice.

Relevant programmes

Under the Zambia Strengthening Climate Resilience Project (PPCR PHASE II) and Zambia Integrated Forest Landscape Project funded by Global Environment Facility (GEF), the World Bank provides farmers with climate risk-related information and supports conservation agriculture, integrated soil fertility management, and agroforestry. It is also training farmers in CSA practices such as precision farming, minimum tillage, improved fertilization, and new drought-tolerant varieties of soya beans.

Under the Increasing Climate Resilience in Energy & Agriculture Systems and Entrepreneurship (INCREASE) Program and Market-led Dairy Innovations Project, the Netherlands Development Organization (SNV) has been working with dairy farmers on promoting CSA practices and installing biodigesters. It is also training farmers in good dairy management, in the use of breeding services such as providers of artificial insemination, and in commercial fodder production. The SNV is linking farmers to Savings and Credit Cooperative Organizations (SACCOs) to enhance their access to financial services. Strengthening dairy cooperatives has also been essential to training farmers.

The Africa Development Bank (AfDB) works in Zambia through the Global Agriculture and Food Security Program Agricultural Productivity and Market Enhancement Project and Livestock Infrastructure Support Project. Specifically, it encourages the use of improved drought-resistant soya and groundnut seeds; dry-season land preparation using minimum tillage; the utilization of fixed planting stations in the form of small, shallow basins; the retention of crop residue; the use of mulch or ground covers; and rotation of crops in the field. The AfDB is also working with seed producers to promote new seed varieties along the two value chains, and is building the capacity of agro-dealers and input suppliers and linking them with producers. Along the livestock value chain, the bank is constructing livestock service centres, milk collection centres, livestock marketing centres, livestock slaughter facilities, rural access roads, district veterinary laboratories, quarantine stations, and veterinary checkpoints.

4. GOVERNANCE, INSTITUTIONAL RESOURCES AND CAPACITY

KEY MESSAGES

» In Zambia,government ministries, departments, and agencies, international development partners, and private-sector actors all are working on developing action strategies to respond to climate change.

» Key institutional players include the Ministry of Finance, the Disaster Management and Mitigation Unit (DMMU), the Ministry of Agriculture (MoA), the Ministry of Fisheries and Livestock, the Zambia Agricultural Research Institute, the Zambia Meteorological Department, and the Ministry of Lands, Natural Resources and Environmental Protection.

» The agricultural sector in Zambia also enjoys support from numerous international partners.

» Meanwhile, the Zambia Climate Change Network, climate change interest groups, public and private universities, and local authorities disseminate information and technical support.

Institutions are critical building blocks for agricultural and climate change interventions in the short or long term. **Several organizations in Zambia incorporate climate change issues into policies and development strategies for concerted action.** These organizations include government ministries, departments, and agencies, international development partners, and private-sector actors (Rooij, 2014).

The Ministry of Finance is one important institution involved in climate investment management. In addition, the Disaster Management and Mitigation Unit (DMMU) of the Vice President's Office is responsible for coordinating resources for disaster response and recovery (Rooij, 2014). Projects related to agriculture and climate change are coordinated and implemented by MoA and have a significant national budget allocated to them. The Zambia Agricultural Research Institute (ZARI) is the national research institute under MoA, spearheading public research on seed varieties. The Ministry of Communications and Transport is home to the Zambia Meteorological Department (ZMD), which is in charge of national environmental information and services such as EWS. The ZMD works closely with the DMMU office (Funder, Mweemba, & Nyambe, 2013). The Ministry of Lands, Natural Resources and Environmental Protection formulates environmental policies, is mandated focal point for climate change, and compiles Zambia's communications to the UNFCCC (Rooij, 2014).

Since the 1900s, Zambia has also benefited enormously from investment in the agricultural sector by international organizations. The World Bank, the United Nations Development Programme, and the Norwegian Agency for Development Cooperation have, for example, supported the Ministry of Environment in setting up its ministry and in developing the National Environmental Action Plan (NEAP) and Disaster Management Policy for 2005. The GEF has also funded NAPA policy and the development of projects. The World Bank, the United States Agency for International Development (USAID), and the German Agency for International Cooperation (GIZ) are currently rolling out numerous projects to transform agriculture, the climate policy agenda, and climate change adaptation and mitigation. Other major development partners include the International Union for Conservation of Nature, which fosters climate change and development in Zambia; the Department for International Development (DFID), which supports social protection programmes; and the Food and Agriculture Organization (FAO), which encourages conservation farming and CSA. The key players in the dissemination of climate change information, advocacy, research, and technical support are members of the Zambia Climate Change Network, climate change interest groups, public and private universities, and local authorities (Funder, Mweemba, & Nyambe, 2013).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5. CLIMATE CHANGE-RELATED RISKS AND VULNERABILITIES

KEY MESSAGES

- Zambian farmers agree that climate change exists and that the weather is increasingly difficult to predict.
- Climate modeling indicates that dry spells, extreme heat events, flood risk, and moisture stress will increase in Eastern and Southern Provinces, along with localized risk of erosion.
- Currently, both groundnuts and soya beans are highly suitable crops in Eastern and Southern Provinces; however, slight, localized decreases in suitability are predicted, especially in Southern.
- The most pressing climate-related hazards in the groundnuts value chain are droughts and floods; soya bean crops, meanwhile, may be impacted by diminished rainfall and changing temperatures; and droughts and extreme rainfall may be harmful to milk production.

5.1. Farmers' perceptions on climate change

Based on their experience of changes in weather and climate, farmers have formed local narratives about climate change trends and impacts. These ideas have influenced their decision making about which strategies to adopt in order to manage the impacts of these perceived changes.

There was consensus among different farmers – both men and women – that climate is indeed changing and the weather has become increasingly unpredictable (Mulenga & Wineman, 2014). Farmers cited causes of climate change as supernatural forces e.g. not respecting the ancestral spirits and environmental causes like deforestation. Some farmers attributed these changes to natural processes and a few did not know of any causes of climate change. Across Zambia, many farmer groups stated that rainfall variability had affected the start and length of the growing seasons. Some farmers were more concerned with the onset and cessation than with the amount of rainfall, while others reported on precipitation length and variability (Mulenga & Wineman, 2014).

Farmers also noted that climate change impacts could be negative to positive. Negative effects included food insecurity while positive included growing of new crops like tobacco in Eastern Zambia. The adoption of adaptation strategies such as conservation farming, diversification, adoption of climate-resilient livestock breeds and crop varieties are connected to perceptions associated with increases in flooding and droughts.

Comparison of perceived changes in climate and observed meteorological data showed that reported experiences of depressed rainfall were inconsistent with a recorded increase over the period from November 2011 to March 2012, for example in Chipata, which is situated in Eastern Province. With regard to temperatures, some farmers in Southern Province indicated there has been no change while farmers in the Northern Province cited temperatures were rising. Some reports were based on daytime temperatures, others on nighttime temperatures. Other climatic changes observed by Zambian farmers included decreasing water levels in rivers and streams, an increased incidence of animal pests and human diseases, and a decline in crop yields.

5.2. Climate change and variability: historic and future trends

In our climate data analysis, for historical precipitation and temperature trends, we used the Climate Hazards Group InfraRed Precipitation with Station and Climate Hazards Group Infrared Temperature with Stations. For future climate projections, we used an ensemble of downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) (Navarro-Racines et al 2020). Specifically, we utilized the MOHC_HADGEM2_ES, CESM1_CAM5, GFDL_CM3, MPI_ESM_LR, and MIROC_MIROC5 models.

The climate analysis for Eastern and Southern Provinces shows that historical (1981-2015) monthly temperatures varied between 10-32°C. The long rainy season, from January through April, was wetter than the second season from late November through December. Dry spells with less than 100 mm rainfall occurred in April and October. January featured the heaviest rainfall, up to 200 mm per month. Most of the land area in both provinces experienced a historical annual mean temperature above 20°C. The annual mean precipitation in the provinces was between 600 and 1100 mm. Southern province was significantly drier and cooler than Eastern province (Figure 3).

CDD defined as Consecutive Dry Days serves as an effective measure for extremely low precipitation and seasonal droughts. In the long rainy season, Eastern province historically experienced less than 24 consecutive dry days (CDDs) characterized by precipitation < 1 mm/day. Southern province, on the other hand, experienced up to 30 CDD. **In the future, CDD in both provinces will increase by 5 to 9 days, suggesting that dry spells will become more common.** Future climate projections also indicate that Southern will experience approximately 38 CDD in the 2050s. Between the 2020s and 2040s, longer stretches of CDD will lead to a high risk of droughts during the long rainy season (Figure 4).

The NT35, defined as the total number of days in a season with maximum temperatures greater than or equal to 35°C, serves as an indicator of heat stress. In the long rainy season, the NT35 has historically remained low with an annual mean of 18 days above 35°C. **However, future climate projections indicate that the NT35 will increase drastically in Eastern and Southern provinces, suggesting that extreme heat events in the long rainy season could last up to four weeks in some areas (Figure 5).** Specifically, the current climate projection under Representative Concentration Pathway (RCP) 8.5 indicates that the number of days with heat stress in Eastern will increase by 27 days. Hot areas in both provinces will become hotter as we move into the 2020s through the 2040s.

The maximum 5-day running average precipitation (P5D) serves as an indicator of flood risk. In the long rainy season, the P5D has historically remained low, below 20 mm, with some scattered larger values. Future climate projections indicate that the P5D will increase significantly, by 5 mm, across Zambia. Eastern Province will experience more extreme rainfall compared to Southern (Figure 6). **The overall increase in the P5D suggests increased flood risk in both provinces.** The hydrological consequences of higher precipitation across 5 days are severer than in the case of precipitation on a single day, so flooding events are likely to be more frequent in the future.

The 95th percentile of daily precipitation (P95) for a season serves as an indicator of heavy rainfall and is linked with the risk of erosion. In the long rainy season, the P95 has historically remained high in Eastern Province. **Future climate projections indicate that the P95 will mainly concentrate in the southern areas of Eastern Province and northeastern regions of Southern Province, suggesting increasing localized erosion risk.** From 1981-2015, the P95 has tended to increase, with most years experiencing values between 12 and 25 mm/day. Future climatic projections predict a decreasing trend, with a few high values, in the 2020s and 2030s (Figure 6). In the future, it is expected that the long rainy season will become wetter, with increasing precipitation in Eastern Province.

Moisture stress, which serves as an indicator of the available soil moisture for plants, is measured as the number of days with a ratio of actual to potential evapotranspiration below 0.5 (NDWS). Higher NDWS values negatively affect the growth of crops and the physiological functions of plants. **Comparison of historical and future trends indicates that moisture stress is expected to increase across both provinces by 8 to 11 days in the first rainy season (Figure 7).** Southern Province, with a high number of CDD, will experience significantly higher moisture stress than Eastern Province.

Figure 3. Historical annual mean precipitation and temperature in the Eastern and Southern Province.

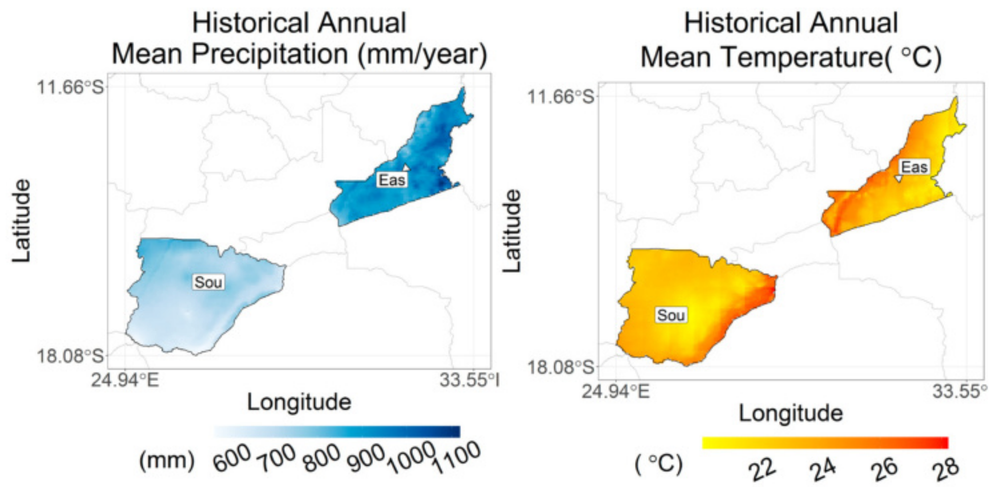


Figure 4. Historical (left), and future projected (center) and projected change (right) for the maximum number of consecutive dry days within the year (all year) (average of last 30 years) for Eastern and Southern Provinces.

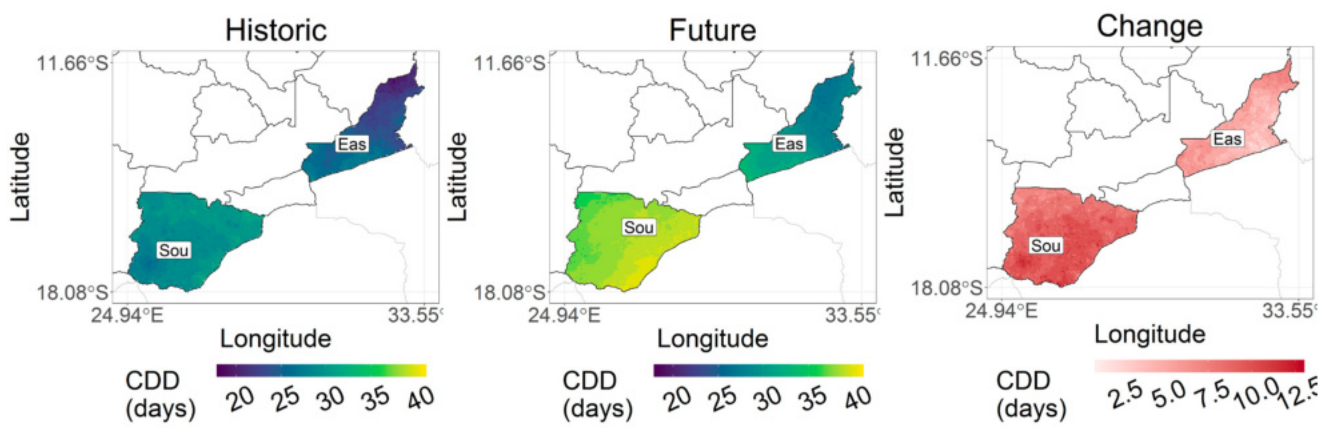


Figure 5. Historical (right), and future projected (center), and projected change (right) for the total number of days with maximum temperature greater or equal to 35°C in the year (average of last 30 years) for Eastern and Southern Provinces.

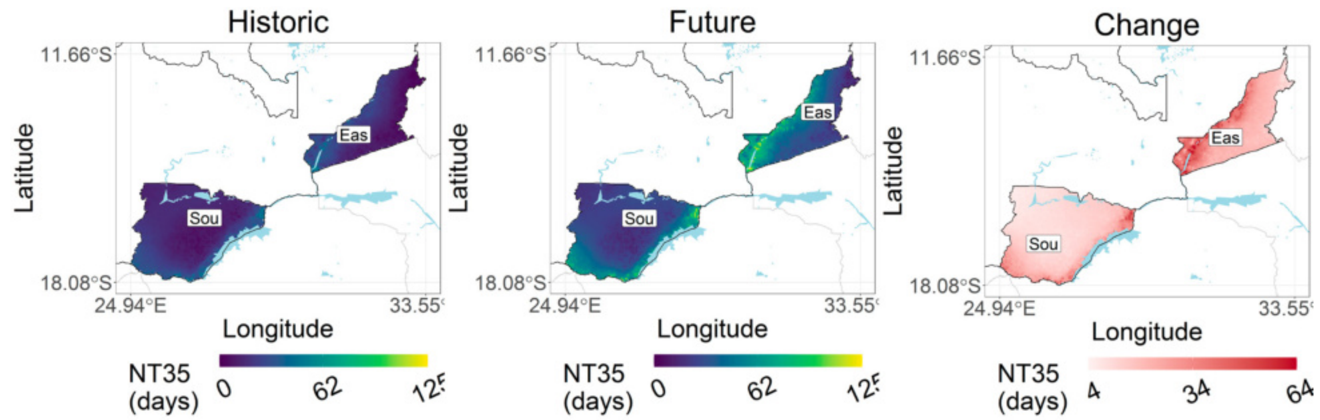


Figure 6. Historical (right), and future projected (center), and projected change (right) for the Maximum 5-day running average precipitation (average of last 30 years) for Eastern and Southern Provinces.

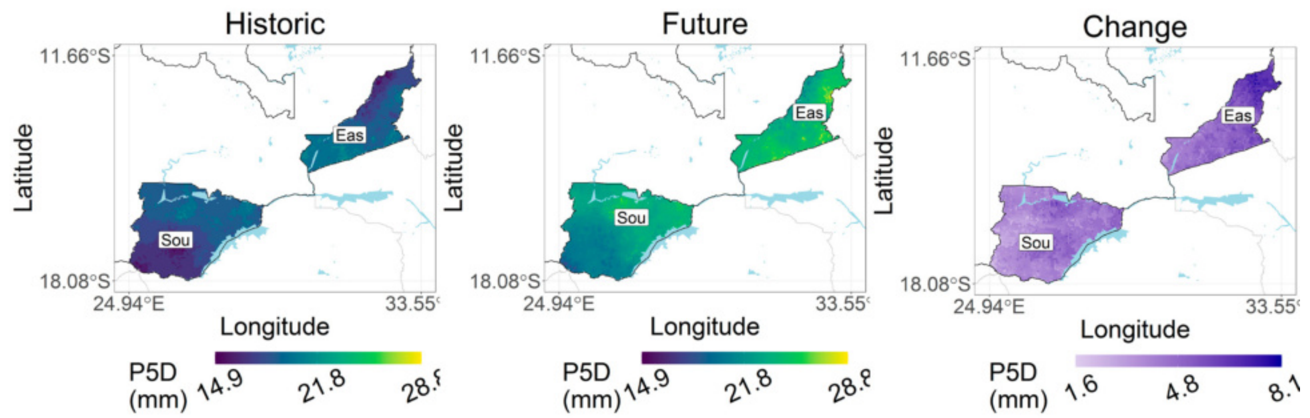
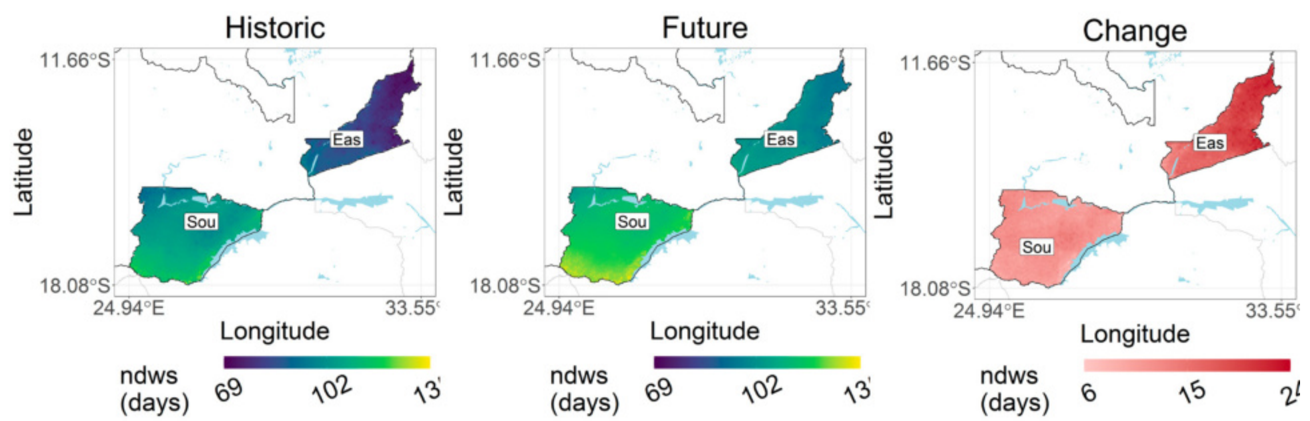


Figure 7. Historical (right), and future projected (center), and projected change (right) for the number of days with moisture stress (average of last 30 years) for Eastern and Southern Provinces.



5.3. Crop suitability analysis

In our crop suitability analysis, we used the EcoCrop model to locate suitable areas for crop production under current and future climate scenarios (Ramirez-Villegas et al 2011). EcoCrop has been used to conduct suitability assessments and understand the impacts of climate change on a large number of crops. The analysis is based on WorldClim v1.4 data for the historical or near-current climate, and on an ensemble of 5 downscaled global climate models for the future under RCP 8.5 (Hijmans et al. 2005; Navarro-Racines et al. 2020). Monthly climate datasets are generated using different types of models. In this study we used global climate models, such as “MOHC_HADGEM2_ES”, named after the agency that developed the model, the Met Office Hadley Centre. we simulated daily records from the monthly datasets and identified various climate hazard indicators (Navarro-Racines et al. (2020). To do this, we used various models depending on the indicator selected; for instance, we used NT35 as the heat stress indicator.

Historically, Eastern and Southern Provinces had high suitability (100%) to produce groundnuts and soya beans. According to our climate analysis, crop suitability analysis for groundnuts will remain high. Slight decreases in suitability will occur in the southern, eastern, and western regions of Southern Province. About 50% of the province will see decreases by 2050. However, small areas of the province will conversely become more suitable (Figure 8). Overall suitability will remain above 80% in 2030 and in 2050. Meanwhile, the suitability of soya beans will remain the same in the entire Eastern Province in 2030 and 2050. Southern Province, however, will become less suitable in the south; suitability will decrease in about 50% of the province by 2050. Overall suitability will remain above 80% in 2030 and in 2050 according our projection (Figure 9).

Figure 8. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability changes of groundnuts production in Eastern and Southern Provinces

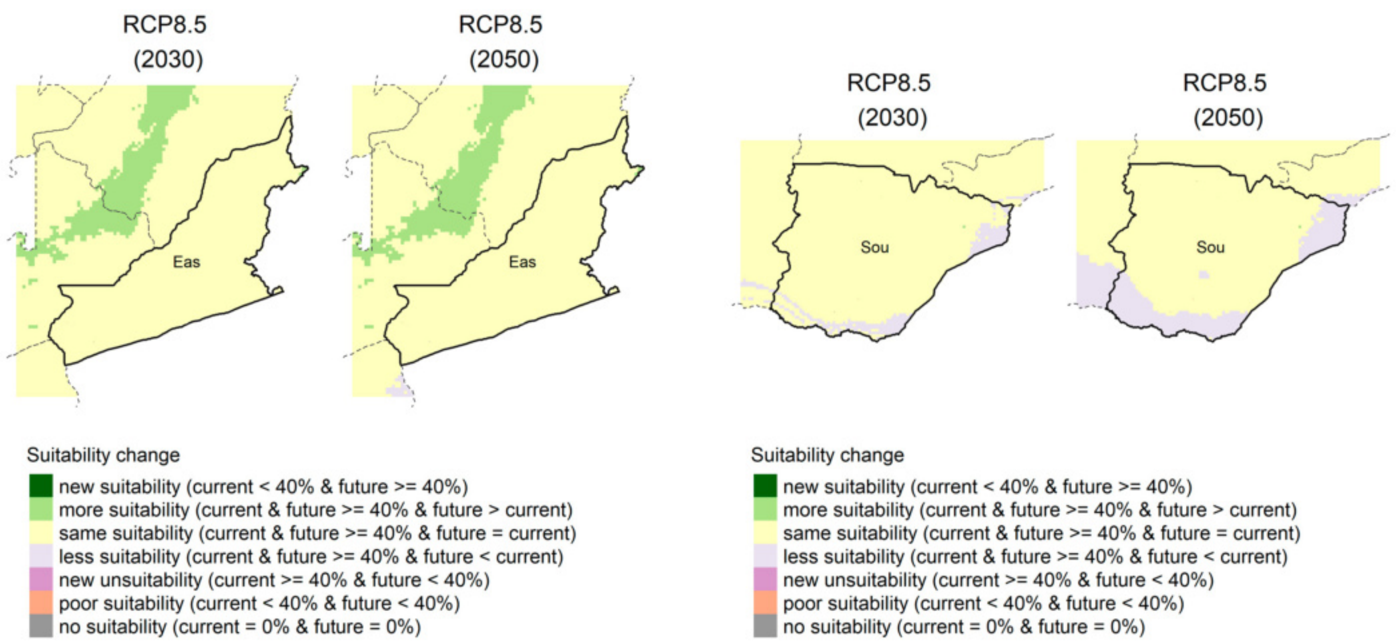
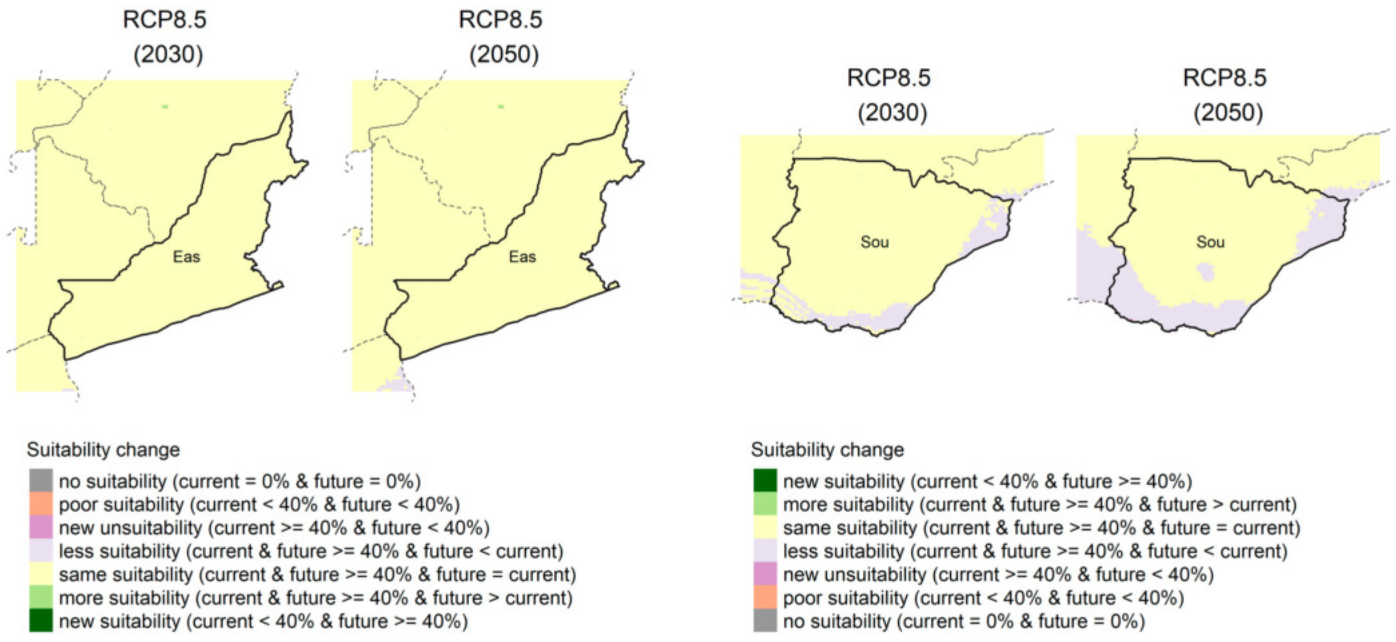


Figure 9. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability changes of soybean production in Eastern and Southern Provinces



5.4. Climate vulnerabilities across agriculture value chain commodities

5.4.1. Groundnuts

Droughts have been a recurrent climate hazard in Eastern and Southern Provinces. They can result in water stress that leads to crop failure during germination. During drought seasons, a hard soil pan develops, which constrains harvesting and land preparation. Hard soil pans also hinder water percolation, consequently interfering with plant initiation and proper pod formation. Groundnuts, while relatively hardy due to their extensive root systems, are sensitive to moisture changes. Soil moisture stress due to drought affects germination, root and shoot development, and flowering. It interferes with the quality – size, shape, and color – of nuts, and reduces their protein and oil content. Additionally, because groundnut farming is more labour-intensive than growing other crops like maize and cotton, ground moisture stress results in a shortage of labour during harvesting periods, resulting in lower productivity. If less marketable produce is generated, this situation in turn diminishes farmers’ ability to purchase required inputs and affects other actors in the value chain. Prices for consumers increase due to higher demand.

Floods are destructive, potentially resulting in increased waterlogging, soil erosion, destruction of infrastructure, and outbreaks of human diseases like malaria. Waterlogging at sowing affects plant germination, potentially resulting in stunted growth and low germination rates, erratic and poor establishment of plants, and consequently, low yields (Sesay, 2009). Low germination rates and stunted growth hamper production and reduce the volume of marketable produce, decreasing the anticipated income of farmers and traders along the value chain. An outbreak of serious fatal diseases like malaria, meanwhile, reduces the availability of labour, and the destruction of infrastructure impedes the transportation of inputs and outputs, affecting all major actors along the value chain.

5.4.2. Soya beans

Diminished rainfall, with low intensity and fewer rainy days, has become common.

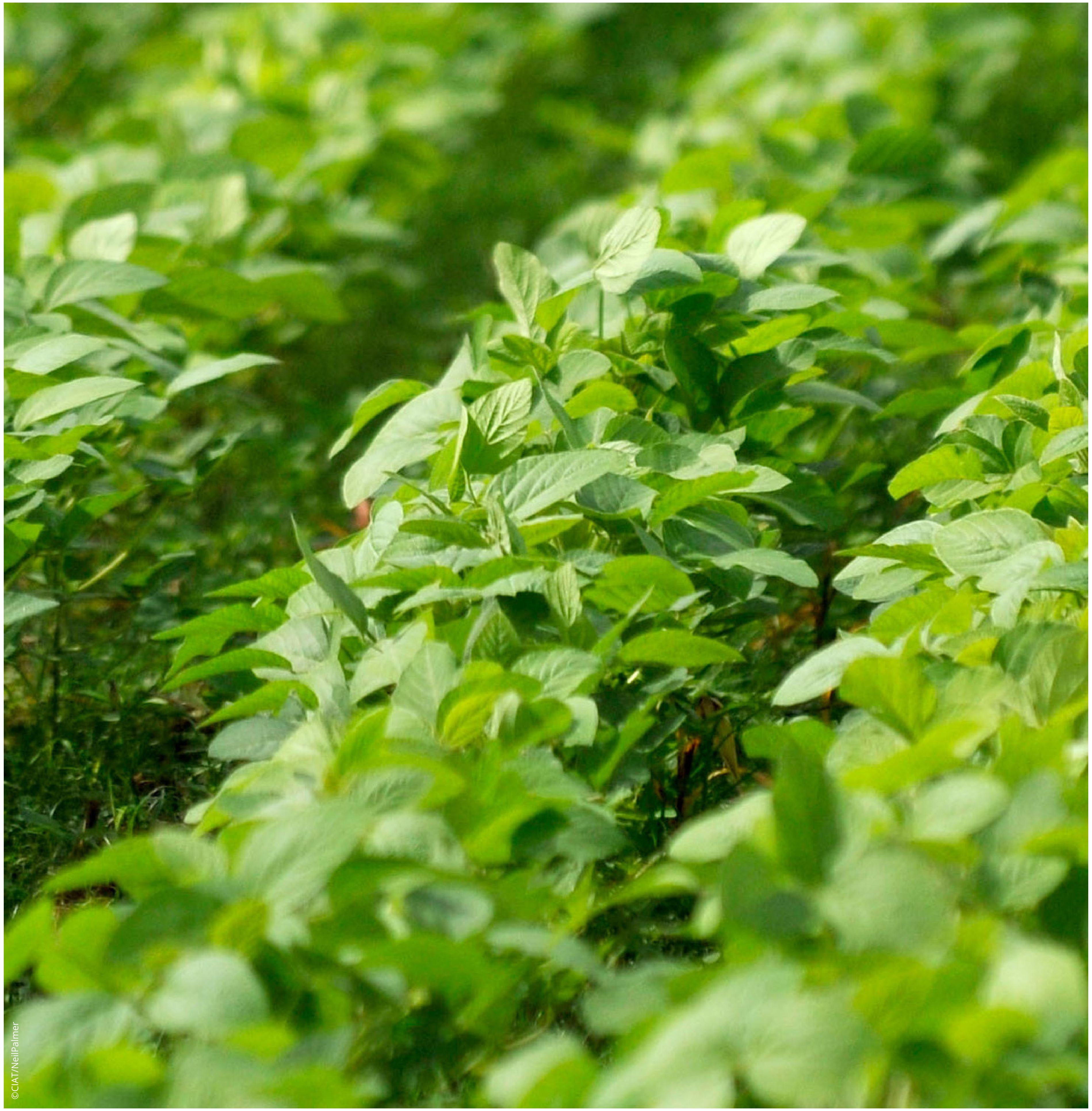
This situation leads to moisture stress, which inhibits the growth of soya beans, resulting in low production. Soya bean plants are highly susceptible to inadequate moisture during their flowering and pod filling stages. Insufficient rainfall severely affects their physiological maturity as it interferes with pod size and weight, requiring supplemental irrigation during these critical stages. If low production reduces the volume of marketable soya beans, prices may increase, negatively affecting consumers and traders. However, this does not necessarily result in increased income for farmers because of the low volumes they produce.

Soya beans are sensitive to temperature changes, which can affect their growth, yield, and quality. High temperatures impact the germination stages and can reduce number of flowers and seeds per pod. High temperatures during flowering can result in pollen sterility and a reduced seed set, potentially leading to smaller production volumes and lower-quality produce. Poor quality and quantities of soya beans negatively affect traders because both factors can increase their transactional cost to source produce. Some traders resort to mixing low quality and high-quality produce and selling at high prices

5.4.3. Milk

Droughts affect fodder production. Scarcity of fodder may compel farmers to reduce their animals' dietary intake or feed quality. Decreasing a cattle's dietary intake diminishes the volume of milk it produces. Sourcing for alternative feed, meanwhile, results in increased cattle movement, which leads to greater incidence of foot-and-mouth disease. In other cases, farmers must purchase feed at an increased price. Additionally, scarcity and low quality of feed may result in reduced quality and quantity of milk. During droughts, temperatures are generally high, and these conditions may result in milk losses due to poor post-harvest handling techniques. High temperatures may also threaten dairy cattle; heat stress and death can occur, especially in young calves. Lower volumes of milk available for sale and processing leads to higher prices, negatively affecting consumers.

Extreme rainfall may enable better fodder growth; however, it may also lead to overproduction of milk. During the rainy season, milk production exceeds processing capacity, resulting in lower milk prices. Lower prices mean less income for farmers, constraining their ability to purchase necessary inputs such as medication and supplements. Excessive rainfall can also have severe impacts on dairy farming, especially when it leads to destruction of structures that shelter the animals or results in flooding that can kill livestock. Additionally, after heavy rainfall, the incidence of foot-and-mouth disease increases, which potentially results in deaths of livestock and increased production costs associated with disease control and management.



6. ADAPTATION TO CLIMATE CHANGE AND VARIABILITY

KEY MESSAGES

- Farmers have developed a variety of ongoing coping strategies to deal with risks related to climate change.
- In addition, the GIC in Zambia has been using different participatory approaches to train farmers and strengthen their adaptation to climate change.
- Stakeholders ranked high-priority adaptation strategies within each value chain, including the use of minimum tillage and good management practices for groundnuts, the use of new varieties of soya beans, and use of improved breeds for milk.
- The highest-ranked innovations in the groundnut and soya bean value chains promise increased yields, although they also involve an element of financial risk.
- Financial support can ensure that most smallholder Zambian farmers will have good outcomes after implementing these adaptation strategies.

6.1. On-farm adaptation strategies

Farmers report employing several coping strategies to maximize their production and limit the adverse effect of climate change risks. These coping strategies include using new, improved varieties adapted to unpredictable rainfall; planting in stages; adopting good agricultural practices like mixed cropping, planting basins, and ripping; and engaging in crop diversification and conservation agriculture. Replanting crops due to delayed rains is common. Some farmers practice crop and income diversification by engaging in off-farm employment and running small businesses. Agricultural practices like minimum tillage, intercropping, crop rotation are specific for soya and groundnuts farming. Lastly, in extreme conditions, farmers sell their assets or borrow money to maintain their livelihoods.

Farmers keep indigenous cattle for livestock and rely on natural grazing to feed their animals. They also devote plots on their farms for their animals to grow grass and forages. They practice mixed farming and diversification to be well adapted to different climatic hazards. When there are dry spells, farmers ration available feed or augment with grain legumes. In addition, seasonal cattle migration is very common in search of pasture and water. In particular, herds from Mumbwa, Mongu and Senanga, during dry spells, travel down to the floodplains. Dairy farmers rely heavily on local awareness for the control of insect pests and diseases in livestock. They are organised in clusters to sell milk to processors and traders jointly.

The GIC in Zambia has been implementing several interventions along the groundnut, soya bean, and milk value chains. It is helping train farmers in improved seed varieties, conservation tillage, crop rotation, and agroforestry. The GIC uses different participatory approaches in capacity building such as a lead farmer network, cooperatives, and radio shows. In the milk value chain, the GIC helps educate farmers about breeding, milk hygiene, animal health, the management of dairy cows, feeding regimes, fodder production, and business skills, and it links them to financial institutions

to enhance their business. Processors are also trained in the use of renewable energy for milk cooling. Additionally, the GIC links farmers and processors to improve service delivery.

6.2. Overall ranking of the adaptation strategies

Stakeholder assessments, conducted using structured questionnaires, identified current and novel adaptations that reduce agricultural risk and help value chain actors adapt to climate change. These experts were sourced from a range of institutions and disciplines. They build on information collected under the climate impact modeling process to identify adaptive strategies. They provide a foundation for understanding both the types and severity of risks to each value chain.

Across the selected value chain commodities, there is a consensus among stakeholders about the importance of growing improved soya bean and groundnut seed varieties that are bred to tolerate or resist present climate hazards and fulfill different consumer needs (Table 1). Other promising adaptation options at the input stage include investment in water conservation technologies and the use of efficient irrigation systems, which will reduce the risks associated with rainfall variability in Eastern and Southern Provinces. For on-farm production, stakeholders agree on the benefits of using climate-smart technologies such as intercropping, crop diversification, conservation agriculture, and integrated pest and disease management. For dairy farmers, improved livestock breeds, feed conservation, animal husbandry practices, and milk hygiene are promising strategies to boost milk production and quality.

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Table 1. Specific practices within each practice group relevant to the focus value chains

PRACTICE GROUPS	GROUND NUT VALUE CHAIN	SOYA BEAN VALUE CHAIN	MILK VALUE CHAIN
Rangeland management			• Pasture commercialization
Conservation agriculture	• Conservation Agriculture • Minimum tillage* • Crop diversification • Intercropping	• Conservation Agriculture • Crop diversification • Intercropping	
Production best practices	• Good agricultural practices • Early planting	• Early planting	• Improved animal husbandry
Risk insurance	• Weather index insurance	• Weather index insurance	• Livestock insurance
Water management	• Irrigation efficiency • Water conservation technologies	• Irrigation efficiency • Water conservation technologies	• Irrigation
Diet management			• Feed conservation • Agroforestry (fodder trees)
Genetic/variety improvement	• Improved varieties	• New varieties* • Improved varieties	• Improved breeds* • Improved animal husbandry
Integrated Pest Management	• Integrated pest management	• Integrated pest management	
Improved storage			• Feed conservation • Milk hygiene

*Denotes that this is the highest-ranked adaptation strategy for its respective value chain.

Other potential adaptation strategies that could help farmers cope with the effects of climate change along the soya bean and groundnut value chains include integrated pest management, water conservation, organic production, early planting, and weather index insurance. The meteorological department can also guide farmers about cropping calendars.

Along the milk value chain, adaptive technologies include agroforestry, especially fodder trees; irrigation; the commercialization of pasture; and livestock insurance. Across each of the three value chains, different adaptation options were identified. There were similar options for multiple value chains addressing similar risks (Table 2).

Table 2. Adapting to climate change: strategies across major value chain commodities

GROUND NUTS	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• High cost of labour and other inputs like seeds due to replanting.	• Onerous land preparation due to hardpans • Poor germination rates.	• Poor nut quality in terms of size, shape, and color • Low volumes of groundnuts for processing • Pest damage.	• Fluctuating market prices due to low volumes reaching trading centres.
Magnitude of impact	MODERATE	SEVERE	MAJOR	MODERATE
Promising adaptation options	• Dry-season land preparation using minimum tillage methods; COMACO "Better Life Book"[5]; conservation farming; agroforestry; lead farmer networks; promotion of early planting; promotion of drought-resistant seeds for soya beans and groundnuts; "Farm Talk" radio show; retention of crop residues; use of mulch or ground cover; strengthening of cooperatives; use of certified seeds from local seed banks.			
Farmers strategies	• Use of manual family labour; use of farmers' or recycled local seed; on farm processing e.g. shelling; use of animal draught power.			
Floods	• Poor labour availability due to incidence of diseases like malaria; • High costs of inputs and labour.	• Waterlogging in groundnut fields; • Poor germination rates; • Crop failure.	• Increased risk of aflatoxin and fungal diseases in storage; • Reduced quality of groundnuts.	• Fluctuating market prices.
Magnitude of impact	MAJOR	SEVERE	MAJOR	MODERATE
Promising adaptation options	• Use of climate resilient varieties; integrated pest management; crop insurance; early warning systems; Good Agricultural Practices (GAPs); soil and water conservation strategies.			
Farmers' strategies	• Crop diversification, re-sowing, use of improved varieties, shifting to higher planting sites.			
Interventions through GIC	• Use of certified seeds from local seed banks; "Farm Talk" radio show; conservation farming; agroforestry; "Better Life Book"; strengthening of cooperatives; lead farmer networks.			

5 A book that increases knowledge on sustainable agriculture through illustrations championed by Community Markets for Conservation (COMACO).

MILK	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• Supplementation of feed or fodder.	• Incidences of pests and disease; increased costs of on-farm production, e.g. disease control and management.	• Low quantities of milk. • Higher costs for processing.	• High demand and low supply, leading to fluctuations in market prices.
Magnitude of impact	LOW	MAJOR	MODERATE	MODERATE
Promising adaptation options	• Construction of livestock service centres, milk collection centres, livestock marketing centres, livestock slaughter facilities, district veterinary laboratories, quarantine stations, and veterinary check points; increasing access to financial services; improved breeding or artificial insemination; commercial fodder enterprises; milk handling, cooling, processing, and hygiene; feeding regimes and fodder production; introduction of livestock insurance; livestock diversification; local processing using renewable energy for milk cooling; better management of dairy cows; enhancement of market linkages; good animal husbandry practices; animal health; a stronger role of dairy cooperatives in service provision through improving their organization, business management, governance, and institutional capacity.			
Farmers strategies	• Seasonal migration of cattle; crop diversification; feed rationing or supplementation; local pests and diseases management practices.			
Extreme rainfall	• Low cost of feeds, since pasture and fodder become readily available.	• Incidences of pests and disease; increased costs of on-farm production, e.g. disease control and management; • Potential for better fodder growth.	• Lower processing costs.	• Higher milk quantities, which could lower milk prices and reduce farmers' incomes.
Magnitude of impact	LOW	SEVERE	LOW	LOW
Promising adaptation options	• Access to financial services and products like insurance and credit facilities, keeping improved climate resilient dairy breeds; integrated pest and disease management; training on proper animal husbandry practices; Diversification.			
Farmers strategies	• Using local practices to manage diseases; engaging in crop diversification; hawking milk using informal market channels; using improved pasture or fodder varieties.			
Interventions through GIC	• Feeding regimes or fodder production; improved genetic breeding or artificial insemination; better management of dairy cows; milk hygiene and training on proper animal health; local processing using renewable energy for milk cooling; broadened access to financial services; commercial fodder enterprises; strengthening cooperatives and SACCOs; market linkages.			

6.3. Cost benefit analysis of the prioritized adaptation strategies

A CBA is critical when making investment decisions, including those associated with CSA practices. This is because a CBA allows for the comparison of costs and returns associated with a given CSA practice versus the status quo, also referred to as business as usual (BAU) or conventional practice (Ng'ang'a et al., 2017). Three CBA indicators, the Net Present Value (NPV), Internal Rate of Return (IRR), and payback period, show the profitability associated with an improved practice or innovation. The NPV measures the incremental flow of net benefits from the innovation over its lifecycle, while the IRR is the discount rate that equates NPV to 0. A higher IRR indicates that an innovation is profitable. The payback period is the number of years it takes to recoup the initial capital invested.

We computed a CBA for the highest-ranked innovations for the groundnut value chain, specifically the use of minimum tillage and good management practices, and for the soybean value chain, specifically the use of new varieties of soya beans. New, improved varieties of soya beans provide high yields and are very resistant to diseases. The use of minimum tillage and good management practices in the groundnut value chain was prioritized, meanwhile, because of its potential to conserve water and provide superior yields. The lifecycle for the use of minimum tillage and good management practices in the groundnut value chain is 10 years, whereas the lifecycle for the use of new seed varieties in the soya bean value chain is 20 years.

The implementation and maintenance of minimum tillage and good management practices in the groundnut value chain requires at least 4% more capital than BAU, whereas the use of improved varieties of soya beans requires 2% more capital (Table 3). These two innovations increased operating costs by at least a 38% as compared to BAU (Table 3). The benefits associated with these two innovations include increased yields per ha, rather than the reduction in the costs of maintenance, installation, and operations. **When compared with BAU, the use of minimum tillage and good management practices in the groundnut value chain increases yields by 80%, and the use of improved varieties of soya beans increases yields by 111% (Figure 10).**

The NPV associated with the use of minimum tillage and good management practices in the groundnut value chain is US$ 2,738 per ha, and the NPV associated with the use of improved varieties of soya bean seeds is US$ 1,562 per ha (Table 4). The IRR associated with the use of minimum tillage and good management practices in the groundnut value chain is 415%, and the IRR associated with the use of improved seed varieties in the soya bean value chain is 252%. Both these IRRs are higher than the prevailing discount rate in the market. Both innovations also have a payback period of one year (Table 4). Innovations with a short payback period tend to appeal to smallholder farmers, whereas a longer payback period can act as a disincentive to adopting and scaling up an innovation.

The risk associated with the use of minimum tillage and good management practice in the groundnut value chain and the use of an improved variety of soya beans value chain was modelled using Monte Carlo Simulations (n=10,000). The results show the probability of making unprofitable returns after investing in the use of minimum tillage and good management practices for groundnuts, and in the use of improved varieties of soya beans (column 6, Table 4). T**he risk associated with the use of minimum tillage and good management practices for groundnuts is about 25%; the same is true of using improved varieties of soya bean seeds.** This figure is calculated given the characteristics of the cumulative density function expressing the probability of the NPV being less than or equal to the costs of adopting these innovations, such as implementation, maintenance, and operation costs (Table 4).

The use of minimum tillage and good management practices in the groundnut value chain and the use of improved seed varieties in the soya bean value chain are both profitable and have a relatively short payback. These innovations, however, carry a considerable risk, a 25% chance of making unprofitable returns, meaning that out of every 1000 farmers who adopts and implements either of these innovations, about 250 may end up making unprofitable returns. This level of risk may be too unbearable for smallholder farmers and may, therefore, be a barrier to their adoption. **This possibility underscores the need for the provision of a sufficient financial support base for farmers to operate at least until they reach the break-even point.**

Table 3. Installation costs for BAU and the two prioritized innovations in the Zambian groundnut and soya bean value chains

VALUE CHAIN (INNOVATION)	INSTALLATION COSTS (US$/HA)			MAINTENANCE COSTS (US$/HA)			OPERATION COST (US$/HA)		
	BAU	IMPROVED SEED VARIETY	*% CHANGE IN COST*	BAU	IMPROVED SEED VARIETY	*% CHANGE IN COST*	BAU	IMPROVED SEED VARIETY	*% CHANGE IN COST*
Groundnuts (Minimum tillage and good management practices)	457	500	*+9*	7,892	8,052	*+2*	739	1,021	*+38*
Soya beans (Use of new varieties)	867	904	*+4*	7,097	7,395	*+4*	753	1,546	*+105*

Figure 10. Yield for BAU versus prioritized innovations

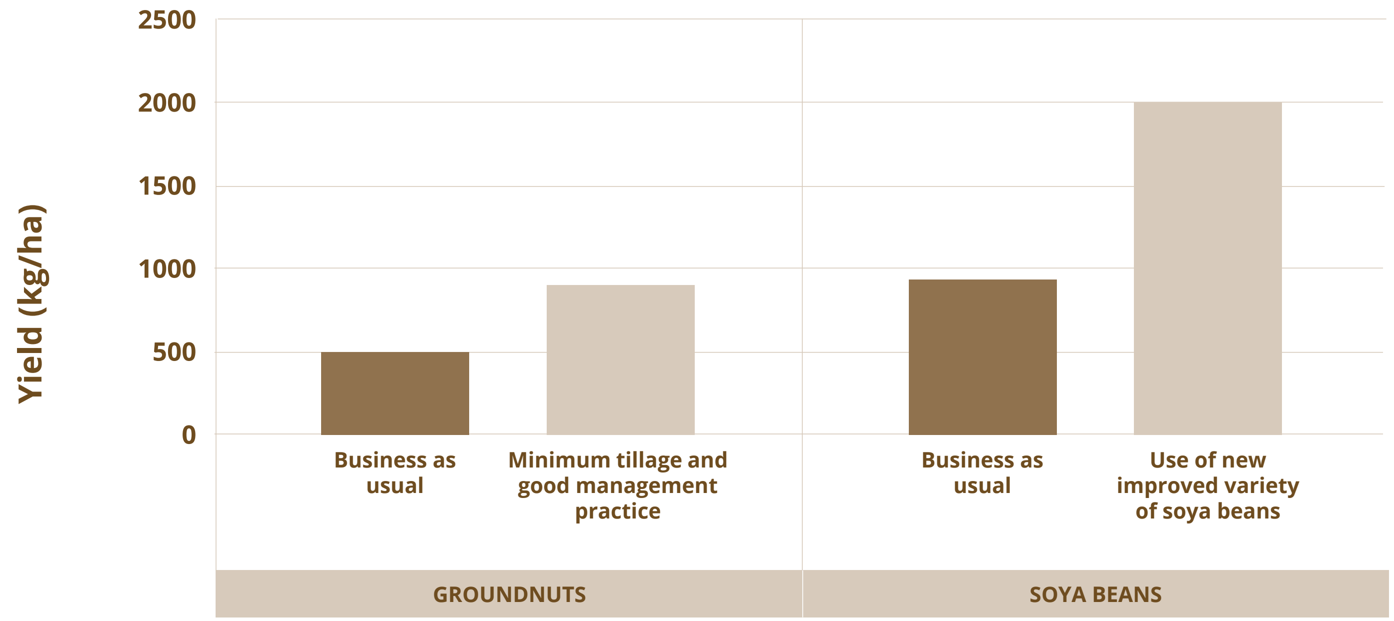

Table 4. Profitability associated with prioritized innovations for Zambian soya bean and groundnut value chains

VALUE CHAIN	INNOVATION	PROFITABILITY INDICATORS			
		NPV IN US$	IRR IN (%)	PAYBACK PERIOD (YEARS)	RISKINESS OF INVESTMENT
Ground nuts	Use of minimum tillage and good management practices in production	2,738	415 (>r)	1	This innovation has about a 26% probability of making unprofitable returns
Soya beans	New, improved varieties of seeds	1,562	252 (>r)	1	This innovation has about a 25% probability of making unprofitable returns

NB: >r implies that the practice is privately profitable

A CBA is important for evaluating innovations, especially when an investment decision needs to be made. There are limitations associated with CBA methodology such as potential inaccuracies when identifying and quantifying costs and benefits for a given innovation. Nonetheless, a CBA is critical for planning, targeting future investments, and identifying potential barriers to scaling up innovations. The use of minimum tillage and good management practices in the groundnut value chain and the use of an improved variety of seeds in the soya bean value chain are both "no-regret options" because they will yield economic benefits now and in the future and are, therefore, important for strengthening future household resilience. These two innovations are both profitable and have a high IRR and a short payback period, and these factors could explain why they emerged as a strong choice for stakeholders during the prioritization process in Zambia. However, when the distribution of the NPV is considered, both innovations have a considerable probability of returning unprofitable results. Yet since they are still profitable, it makes economic sense to promote them for scaling up. **If they are so promoted, sufficient financial support needs to be provided to ensure that they produce desirable outcomes for a majority of smallholder farmers in Zambia.**

7. SYNTHESIS AND RECOMMENDATIONS

Climate projections indicate that climate change-related variability will increase in frequency and severity in the 2020s through the 2050s. Extreme climate hazards like droughts and floods will become frequent and severe, affecting food security, disrupting livelihoods, and widening existing inequalities. To enhance Zambia's national adaptive capacity, collaborative, large-scale action will be necessary, involving farmers, the government, non-governmental organizations, civil society, and private-sector institutions.

According to our CBA, the use of minimum tillage and good management practices in the groundnut value chain and the use of improved varieties of soya beans are both profitable and have a relatively short payback period; however, these innovations carry a considerable risk. Therefore, for value chain interventions to be effective, it is important that implementing actors draw on the experiences, needs, demands, and priorities of potential beneficiaries.

Going forward, high potential activities for addressing climate risk in Zambia include practice groups spanning input optimization, good production practices, and post harvest. A variety of opportunities for collaboration, funding, and synergies exist for these practices (Table 5). In addition, common challenges and opportunities are observed across all practices. For example, common barriers that challenge the general implementation of climate-aware programming in Zambia include low capacity, high cost of inputs, little or no access to financial services, persistently low yields, and labor shortages. Additionally, several organizations are well positioned to offer general support across all potential activities, including:

- Ministry of Finance
- Disaster Management and Mitigation Unit (DMMU) of the Vice President's Office
- Ministry of Agriculture
- Ministry of Fisheries and Livestock
- Zambia Agricultural Research Institute (ZARI)
- Zambia Meteorological Department (ZMD)
- Ministry of Lands, Natural Resources and Environmental Protection
- Zambia Climate Change Network
- The World Bank
- United Nations Development Programme
- Norwegian Agency for Development Cooperation
- Global Environment Facility
- United States Agency for International Development (USAID)
- German Agency for International Cooperation(GIZ)
- International Union for Conservation of Nature
- Department for International Development (DFID)
- Food and Agriculture Organization (FAO)

Table 5. Practice-group specific potential strategies and considerations for advancing CSA at scale

PRACTICE GROUP	PARTNERSHIPS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Rangeland management	• World Bank (Global Environment Facility) • Netherlands Development Organization (SNV)	• Good potential for blended green finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency
Conservation agriculture	• World Bank (Global Environment Facility) • Africa Development Bank (AfDB) • 7th National Development Plan	• Good potential for blended green finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term productivity	• Improved soil health supports yields and water retention, thus increasing both market stability and climate resiliency
Production best practices	• Africa Development Bank (AfDB)	• Good potential for blended green finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term productivity	• Supports climate-resiliency and yields, thus improving market stability
Diet management		• Good potential for blended green finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term productivity	• Supports climate-resiliency and yields, thus improving market stability
Integrated Pest Management		• Good potential for blended green finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term productivity	• Supports both productivity and environmental/land restoration goals

PRACTICE GROUP	PARTNERSHIPS	EXISTING AND POTENTIAL FUNDING	SYNERGIES
Risk insurance		• Public and private interests with good blended finance potential	• De-risks changes toward unknown new production practices and continued production in the face of climate change
Water management		• Public and private interests with good blended finance potential	• Supports climate-resiliency and yields, thus improving market stability
Genetic/variety improvement	• Netherlands Development Organization (SNV) • World Bank (Global Environment Facility) • Africa Development Bank (AfDB)	• International research funding offers robust support; diversification toward local and culturally important crops needed	• Supports climate-resiliency and yields, thus improving market stability
Improved storage	• Africa Development Bank (AfDB)	• High potential for private sector investing	• Reduces losses, thus increasing profits and supporting markets stability, particularly inter-seasonally

** based on literature

The inadequacy of practical skills and knowledge related to adaptive technologies in the agricultural sector, and specifically in the soya bean, groundnut, and milk value chains, calls for stronger sensitization and farmer training programmes. For example, climate-smart mechanization is necessary to reduce drudgery in farming activities for soya beans and groundnuts. Similarly, to increase milk productivity and link farmers to markets, they need knowledge and skills for improved animal husbandry practices. In addressing these challenges, it is important to consider gender roles, responsibilities, and benefits across the stages of the value chain in order to identify technologies that are beneficial to both men and women. Overall, interventions should save costs, increase production, and improve incomes.

In addition to technologies, it is also important to invest in the enabling environment to support climate change adaptation. There is a variety of ways to enhance adaptation efforts across Zambia. Examples include linking science to decision making through extensive research and data collection; eliminating barriers that hinder policy and decision making at the sub-national level; and monitoring and evaluating the efficiency of policies, strategies, and programmes. Different types of services such as climate information, agro-advisories, financial services, and access to electricity can help furnish favorable conditions for development of all three value chains.

8. WORKS CITED

Central Statistical Office. (2016). Post Harvest Survey 2014-2015 Agriculture season (Small and Medium Scale Farms) . Lusaka: Central Statistical Office.

Central Statistical Office. (2013). 2010 Census of population and housing; Population and Demographic Projections 2011-2035. Lusaka: Central Statistical Office. Retrieved from https://www.zamstats.gov.zm/phocadownload/Zambia%20Census%20Projection%202011%20-%202035.pdf

Desmae, H., & Sones, K. (2017). Groundnut cropping guide. Nairobi: Africa Soil Health Consortium.

Funder, M., Mweemba, C. E., & Nyambe, I. (2013). The climate change agenda in Zambia National interests and the role of development cooperation. Denmark: Danish Institute for International Studies, DIIS.

Groundnut Growing Training Manual. (2020). Retrieved from https://www.mamachakula.com/uploads/5/1/2/6/51260451/groundnut_growing_training_manual_korrektur_gelesen_4.pdf

Kawambwa, P., Hendriksen, G., Zandonda, E., & Wanga, L. (2014). Business Viability assessment study of small holeder dairy farming in Zambia. Wageningen: Alterra Wageningen UR.

Lubungu, M., Burke, W. J., & Sitko, N. J. (2013). Analysis of the Soya Bean Value Chain in Zambia's Eastern Province. Lusaka: Indaba Agricultural Policy Research Institute (IAPRI).

Mafimisebi, Taiwo E. & Chibalani, Cletus & Yerokun, Olusegun A. & Syampaku, Edward S. (2015). "Gender Differential in Profitability and other Aspects of Smallholder Soybeans Production in Eastern Province, Zambia," 2015 AAEA & WAEA Joint Annual Meeting, July 26-28, San Francisco, California 202758, Agricultural and Applied Economics Association.

Ministry of Health (MOH) (2020). Zambia Demographic and Health Survey 2018. Lusaka: Zambia Statistics Agency. Retrieved from https://www.zamstats.gov.zm/phocadownload/Demography/Zambia%20Demographic%20and%20Health%20Survey%20-%202018.pdf

Mukuka, R. M., & Shipekesa, A. M. (2013). Value Chain Analysis of the Groundnuts Sector in the Eastern Province of Zambia. Lusaka: The Indaba Agricultural Policy Research Institute (IAPRI). Retrieved from http://www.bdsknowledge.org/dyn/bds/docs/881/GroundnutsSector_EasternZambia_IAPRI.pdf

Mulenga, B. P., & Wineman, A. (2014). Climate Trends and Farmers' Perceptions of Climate Change in Zambia. Lusaka: Indaba Agricultural Policy Research Institute (IAPRI). Retrieved from http://www.aec.msu.edu/fs2/zambia/index.htm

Mulungu, K., & Ng'ombe, J. N. (2017). Sources of Economic Growth in Zambia, 1970–2013:A Growth Accounting Approach. Multidisciplinary Digital Publishing Institute.

Mumba, C., Pandey, G. S., & Jagt, C. v. (2013). Milk production potential, marketing and income opportunities in key traditional cattle keeping areas of Zambia. Livestock Research for Rural Development, 25(4).

Navarro-Racines, C., Tarapues, J., Thornton, P. et al. (2020). High-resolution and bias-corrected CMIP5 projections for climate change impact assessments. Sci Data. 7, 7.

Ndiyoi, M., & Phiri, M. (2010). Livelihood zones analysis; A tool for planning agricultural water management investments. Farming Systems Association of Zambia (FASAZ). Lusaka: FAO.

Pandey, G. S., & Voskuil, G. J. (2011). Manual on improved feeding of dairy cattle by smallholder farmers. Lusaka: Golden Valley Agricultural Research Trust.

Ramirez-Villegas, J., Jarvis, A. & Läderach, P. (2013). Empirical approaches for assessing impacts of climate change on agriculture: the EcoCrop model and a case study with grain sorghum. Agric. For. Meteorol. 170, 67–78 .

Rooij, J. V. (2014). The coordination of climate finance in Zambia. African Climate Finance Hub.

Seed Co. (2019). Soya beans growers guide. Seed Co Zambia International Limited, Lusaka. Retrieved from https://www.seedcogroup.com/sites/default/files/Soya%20Growers%20Guide.pdf

Sesay, A. (2009). Influence of flooding on bambara groundnut (Vigna subterranea L.) germination: Effect of temperature, duration and timing. African Journal of Agricultural Research, 4(2), 100-106.

Siamabele, B. (2019). Soya Beans Production in Zambia: Opportunities and Challenges. American Journal of Agricultural and Biological Sciences, 14(1), 55-60. doi:https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.3844%2Fajabssp.2019.55.60

USDA. (2015). Zambia Agricultural Economic Fact Sheet. Global Agricultural Information Network, 4.

World Bank. (2020). Retrieved from https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=ZM

ZamStats. (2019). 2019 Quarter Three Gross Domestic Product. Zambia Statistics Agency. Lusaka: Zambia Statistics Agency.

ZARI. (2013). Double soybean yields, increase income through good agricultural practices. Lusaka: Africa Soil Health Consortium.

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